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NUMERICAL EXAMPLES
IN HEAT

R. E. DAY.

HEAT

LONDON: PRINTED BY
SPOTTISWOODE AND CO., NEW-STREET SQUARE
AND PARLIAMENT STREET

NUMERICAL EXAMPLES IN HEAT

FOR THE USE OF
TEACHERS AND STUDENTS PREPARING FOR
SCIENCE EXAMINATIONS

WITH ANSWERS

BY

R. E. DAY, M.A.

LONDON
LONGMANS, GREEN, AND CO.
1875

PREFACE.

MOST TEACHERS have probably noticed the difficulty experienced by the younger students in a physical laboratory in reducing the numerical results obtained from their experiments to a tangible form. They have obtained the raw material, but are either utterly ignorant of, or at any rate inexperienced in, the various processes by means of which it is to be converted into the finished article, and much time and trouble would be saved by their having had a little previous practice in such work.

THE OBJECT of this collection of examples is to familiarise the student with the formulæ and tables which are to be found in most of the elementary treatises on Heat, and to afford him sufficient exercise in the numerical solution of such problems as are of frequent occurrence in the practical applications of the subject.

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NUMERICAL EXAMPLES IN HEAT.

CONVERSION OF THERMOMETRIC SCALES.

(1.) What degree on Réaumur's scale corresponds to 23° Centigrade ?

(2.) Express the temperature 78° C. according to Fahrenheit's scale.

(3.) How many degrees Centigrade are 61° R. ?

(4.) Express 93° F. on the Centigrade scale.

(5.) What degree on Réaumur's scale corresponds to 105° of Fahrenheit ?

(6.) What degree of Fahrenheit's scale corresponds to the temperature —12° R. ?

(7.) The density of water is greatest at 3°·9 on the Centigrade scale ; what is the same temperature called on Fahrenheit's scale ?

(8.) The standard temperature not unfrequently referred to in English experiments is 60° F. ; what would the same temperature be called on the Centigrade scale ?

(9.) If the Centigrade thermometer stood at 5° below zero, what would the same temperature be marked on Fahrenheit's scale ?

(10.) What degree on the Centigrade scale would be equivalent to —4° on Fahrenheit's scale ?

(11.) The point at which mercury freezes is indicated by

the same number on the Centigrade and on Fahrenheit's scale; determine the number.

(12.) The scale of a thermometer between the freezing and the boiling point is 65 millimetres in length; what is the length between each division (*a*) on the Centigrade and (*b*) on the Fahrenheit scale?

(13.) In another thermometer the distance between the boiling and freezing points is 105 millimetres. What is the length between each division on the same two scales?

(14.) The sum of the readings of a thermometer graduated both on Fahrenheit's and the Centigrade scale is 60; what is the temperature?

(15.) The difference of the readings of the same thermometer on another occasion was 40; what was the temperature?

LINEAR EXPANSION OF BODIES.

(1.) The length of a wrought-iron rail at 0° C. is 2·5 metres; find its length at 30° C.

(2.) A rod of zinc at 0° C. is ·3 metres long; find its length at 40° C.

(3.) A brass rod is ·5 metre long at 40° C.; what will be its length at 0° C.?

(4.) A glass rod at 25° C. is 2 metres long; what will be its length at 400° C.?

(5.) What must be the length of a brass rod at 15° C. in order that at 0° C. it may be exactly 2 metres long?

(6.) The length of an iron girder-bridge at 0° C. is 200 feet; what will be its length when, by the heat of the summer sun, its temperature has risen to 40° C.?

(7.) What will be the length of the same bridge in winter, when its temperature is −20° C.?

(8.) A copper rod which was 1·5 metres long at 0° C. was found to have increased in length by 2·6 millimetres, owing to a rise of 100° C. in its temperature; find the coefficient of linear expansion of copper.

(9.) A brass rod at 15° C. was found to measure exactly 1·8 metres in length; what will be its length at a temperature of 75° C.?

(10.) An iron rod at a temperature of −20° C. was 15 feet long; what would be its length at a temperature of + 36° C.?

(11.) The railroad between London and Edinburgh is 400 miles long. Iron expands ·00000686 of its length for every degree Fahrenheit. Taking the extremes of summer and winter temperatures at 70° F., show that the expansion of the rails for this difference would be about 338 yards, and that, therefore, it is obvious that the rails must not be placed in contact.

(12.) When the bob of a pendulum vibrating seconds, was let down the hundredth of an inch, the clock lost 10 seconds in twenty-four hours. Assuming that a change of temperature equal to 30° F. alters the length of the rod by about the 5,000th part, show that the consequent error in the rate of going will be about eight seconds per day.

(13.) At a given temperature an iron pendulum of length 3·167 feet beats seconds, how many oscillations less per day will it make when the temperature has risen 20° C.?

(14.) A Graham's mercurial pendulum consists of a glass rod, to the bottom of which is attached a glass vessel for the reception of mercury. If the length of the pendulum be L, express as a fraction of L the height at which the mercury in the vessel must stand in order that, under the simultaneous expansion by heat of the glass rod and the mercury, the point of oscillation may remain the same.

(15.) Find the length of a bar of cast-iron at a temperature of 100° C., whose length at 18° C. is 5 feet. (The coefficient of expansion of cast-iron is ·00001125.)

(16.) A thin rod of steel, 10 feet long, vibrates about an axis passing through one end of it. The time of one oscillation is 1·434 of a second. Find the number of vibrations it will lose per day if the temperature be increased by 15° F.

(17.) An iron pendulum 4 feet long makes 78,030 oscillations in one day. On another day it is observed to make only 78,021 oscillations in the day. Taking the coefficient of expansion of iron for 1° C. at ·000012204, find the change of temperature.

(18.) A bar of iron 10 feet long at zero is heated to 80° C.; find its length, the coefficient of expansion of iron being ·0000122.

(19.) At the temperature 15° C. the height of the mercury column of a barometer was observed to be 762 millimetres: what will be its height at 0° C., and what correction must therefore be applied to the observed height to reduce this to the normal temperature of 0° C.?

(20.) At a temperature of 18° R. the height of the barometric column was observed to be 733 millimetres; reduce this to the normal temperature of 0°.

(21.) Reduce an observed barometric observation of 764·4 millimetres at a temperature of 20° C. to the standard temperature of 0° C.

(22.) In the case of accurate barometric observations it is necessary, in addition to the correction for the expansion of the mercury by heat, to apply a similar one on account of the metallic scale, especially when, as we shall suppose in the present case, the divisions have been made on a movable strip of metal which extends from the lower to the upper end of the mercury column. If 10° C. was the observed temperature of the scale at the time when its subdivision was effected, and 756 millimetres its length, or that of the corresponding barometric column when reduced to 0° C., and ·0000188 the coefficient of linear dilatation of brass, the metal of which the scale is made, what will be the value of x, its length at 15° C., and that of the corresponding correction to be applied to the observed barometric height?

(23.) An English barometer, with a brass scale correctly

graduated at 62° F., reads 29·71 inches at 45° F. What is the pressure in true inches of mercury reduced to the specific gravity it has at 32° F.?

(24.) The same barometer reads 30 inches at 60° F.: what is the pressure in true inches of mercury at 32° F.?

(25.) The same barometer read 30·09 inches at 58° F.: find the true pressure in inches of mercury at 32° F.

(26.) If the brass scale of a barometer has the correct length at 10° C., find the temperature at which the observed reading will require no temperature correction; the coefficient of expansion of mercury being ·00018 and the coefficient of linear expansion of brass being ·0000188.

(27.) The area of the upper surface of a rectangular plate of cast iron at 0° C. is equal to 20 square decimetres; what will be its area if its temperature be raised to 80° C.?

(28.) If the radius of a brass circle at 0° C. be 5 centimetres, by how much is the area of this circle greater at 36° C. than it is at 0° C.?

(29.) A cast iron plate at 10° C. has a surface area of 10 square feet; what is its size at 20° C. and at 0° C. respectively?

(30.) At a temperature of 25° C. the height of the barometric column was observed to be 752 millimetres: calculate the height of the column at the same atmospheric pressure, but at the temperature of 0° C.

(31.) The coefficients of linear expansion of wrought iron and brass are given in a table as being ·00118 and ·00189 respectively between 32° and 212°: if a tube of brass and a tube of iron be each 11 feet long at 32°, what will be the difference in their lengths when heated to 340°?

(32.) The rails from London to Manchester are 188 miles long: suppose these rails to form one continuous piece at a temperature of 0° C., what will their length be at 20° C., the coefficient of expansion of iron being ·0000118?

CUBICAL EXPANSION OF SOLIDS, LIQUIDS, AND GASES.

(1.) The volume of a mass of lead being a cubic foot at 60° F., what will be its volume at 0° F., and what at 88° F.?

(2.) A glass globe at a temperature of 10° C. holds exactly one litre of water; how much will it contain if filled with water at 90° C.?

(3.) The diameter of a brass ball at 0° C. is 5 centimetres; find its diameter at 100° C.

(4.) A hollow cube of zinc has at 0° C. an internal capacity of 27 cubic decimetres; find its internal capacity at 32° C.

(5.) A glass vessel with a narrow neck has a fixed mark on the neck, and its internal capacity at 0° C. up to this mark is 1,000 cubic centimetres; find the capacity of this vessel at 100° C.

(6.) The specific gravity of lead at 0° C. is 11·352; find its specific gravity at 100° C.

(7.) Kopp determined experimentally that the coefficient of cubical expansion of soft soda-glass was ·000026, while for hard potash-glass it was ·000021. What would be the coefficient of linear expansion for these two kinds of glass?

(8.) If the coefficient of cubical expansion of quartz be ·000042, what would be its coefficient of linear expansion?

(9.) What part of its volume at 60° F. is the expansion of a body for each additional degree of temperature, if it expand ·005 parts of the volume which it has at 32° for each degree above 32°?

(10.) A glass bulb is exactly filled by 60 grammes of mercury at 30° C.; what is the internal capacity of the bulb at 0° C.?

(11.) Find the density of mercury at 175° C., its density at zero being 13·598, and its mean coefficient of expansion between those temperatures being ·000183.

(12.) A glass tube, closed at one end, was drawn out at the other to a capillary point. It was weighed, then filled with water and weighed again, and the weight of the water at 0° C. was found to be 186 grammes. By heating the apparatus up to 100° C. nine grammes of water were driven out. Assuming the coefficient of cubical expansion of glass to be ·000026, find the expansion of water between 0° C. and 100° C.

(13.) The specific gravity of mercury compared with that of water at 68° is 13·568, and at 212° is 13·932. If the expansion of mercury between these points be $\frac{1}{68}$th of its volume at the lower temperature, find that of water between the same points.

(14.) At 18·9° C. the weight of a cubic foot of distilled water is 997·84 ounces, and at 16·$\frac{2}{3}$° its weight is 998·24 oz.; find the temperature at which it will be 1,000.

(15.) What volume will a quantity of oil occupy at 92° C., which at 0° C. exactly measures one litre; coefficient of expansion ·001?

(16.) Supposing one bought a litre of spirits of wine at a temperature of −10° C. What space would this occupy at +32° C.? The coefficient of expansion is ·001.

(17.) If the specific gravity of absolute alcohol at 0° C. is ·793, what is it at 20° C.?

(18.) If the volume of a certain quantity of mercury at 0° C. be 5 cubic centimetres, what will it be at 80° C.?

(19.) If 24 cubic centimetres of mercury at 15° C. be warmed up to 100° C., what volume will it occupy?

(20.) If 20 litres of water at 0° C. be heated up to 100° C., what volume will it occupy? (Neglecting the consideration of any loss through evaporation.)

(21.) The density of mercury at 0° is 13·6, what is it at 15° C.?

(22.) If the tube of a thermometer be ·1 inch in diameter, and the distance between the boiling and freezing points be 7 inches, determine the capacity of the bulb, or volume below the freezing point, assuming the expansion of mercury to be ·0001 for 1° F.

(23.) A thermometer, open at the top, is filled with mercury, which weighs 1,250 grains, and the temperature of which is 32°; on being exposed to a higher temperature 4·5 grains of mercury are expelled; find this temperature, the expansion of mercury in volume being ·018 from 32° to 212°.

(24.) A glass vessel with a narrow neck was filled with water at a temperature of 0° C., and the weight of the water was found to be 124 grammes. When the vessel had been heated to 100° C., 6 grammes of water had escaped; deduce from this the expansion per unit of volume of the water, the coefficient of cubical expansion of the glass being assumed = ·000026.

(25.) In an experiment according to Dulong and Petit's method for determining the coefficient of absolute expansion of mercury, the heights of the two columns of mercury, as determined by the cathetometer, were 222 and 226 millimetres respectively, the temperature of the two tubes being 100° C. and 0° C. respectively; deduce the coefficient of absolute expansion of mercury.

(26.) If two volumes of 2 litres and 3 litres of two different gases at pressures of 752 and 760 millimetres respectively, and the same temperature, 15° C., are mixed together and the volume of the mixture is 4 litres, and its temperature 5° C., determine the pressure.

(27.) What volume will 100 cubic metres of air at 0° C. take up if the temperature of the air be raised to 100° C., the pressure remaining constant?

(28.) Two vessels contain air having the same temperature of 14° C., but different pressures, namely, 762 and 765 millimetres of mercury; the temperature of each being increased by 20° C., find which has its pressure most increased.

(29.) If the vessels be of the same size and be allowed to communicate with each other, find the pressure of the mixture at a temperature of zero.

(30.) 1·5 litres of air at a temperature of 27° C. is subject to a pressure represented by a barometric column of 720 millimetres; what volume will this mass of air occupy at the standard temperature and pressure?

(31.) A cylindrical vessel, closed at both ends, and placed so that its axis is vertical, is half filled with mercury at a temperature 0° C., the remaining portion being occupied by air at the same temperature. The expansion of mercury between 0° and 100° C., being ·018 of its original volume, and that of air ·3665 of its original volume for the same pressure, show that if the temperature be raised to 20° C. the pressure of the air will be increased in the ratio of 1·0772 to 1.

(32.) A mass of air of 800 cubic feet volume, 15 pound tension (per square inch) and 10° C. temperature, is heated in a blast furnace to 200° C. and acquires a tension of 19 lbs.; what space will it occupy?

(33.) A litre of air at 0° C., and 760 millimetres pressure weighs 1·293 grammes; what will it weigh at 15° C. and 763 millimetres of barometric pressure?

(34.) The temperature of the air in an extensible spherical envelope is gradually raised 4° C., and the envelope is allowed to expand till its radius is four times its original length; compare the pressure of the air in the two cases.

(35.) A mass of air at a temperature 14° C. is contained in a cylinder which has an air-tight piston fitting into it, and it is found that the air exerts a pressure of 14 lbs. per square inch on the piston. The air being now suddenly compressed into $\frac{1}{6}$th of its former volume, and the temperature changed to 20° C., find the pressure on the piston.

(36.) If 273 volumes of gas be at the temperature of 0° C., to what temperature must they be heated to expand to 295 volumes?

(37.) A balloon containing 1,200 cubic metres of coal gas, under a pressure of 770 millimetres of mercury, ascends until the barometer stands at 530 millimetres; what volume would the gas in the balloon now occupy supposing none to have escaped?

(38.) A glass globe, filled with atmospheric air at 0° C. and at 760 millimetres pressure, was weighed, and then, while open, so that the pressure should remain constant, it was heated to 100° C. and then sealed hermetically. Upon weighing it again it was found that a mass of air weighing 1 gramme had escaped. What was the internal capacity of the globe and the weight of air contained in it at 0° C.?

(39.) Required the internal capacity of a glass globe which, when filled with dry air at 20° C. and 755 millimetres pressure, weighed 567·949 grammes, when filled with pure water at the same temperature weighed 6,133·162 grammes, and when exhausted to a vacuum of 5 millimetres pressure weighed 561·291 grammes.

(40.) Calculate the temperature at which air possesses a density equal to that of hydrogen at 0° C.

(41.) Apply Gay-Lussac's law for the expansion of gas to the following: a gas occupies 1,000 cubic inches at 42° F., what volume will it occupy at 42° C.?

(42.) Volumes of 1, 2, 3 litres of the same gas at the same temperature, and at the respective pressures of 1, 2, 3 atmospheres, are mixed, and the volume of the mixture is reduced to 4 litres; find the pressure of the mixture—

(1.) When the temperature is the same as that of the components;

(2.) When the temperature of the mixture is 100° C., that of the components being 50° C.

(43.) One cubic foot of oxygen, 2 cubic feet of nitrogen, and 3 cubic feet of hydrogen, all at the same temperature, and at the pressure of 30 inches of mercury, are allowed to mix without chemical combination, and the mixture is compelled to occupy a space of 2 cubic feet. When it is reduced to the original temperature of the gases, what will be its pressure?

(44.) Find the volume of dry gas at the standard temperature of 0° C. and the standard pressure of 760 millimetres of mercury from the following observations:

Observed volume of dry gas . . = 160·5 cmtrs.
Height of mercury in tube above that in trough . . . = 15 mms.
Height of barometer in the laboratory . . . . = 747 mms.
Temperature of the room . . = 14·5° C.

(45.) Two vessels contain air at the same pressure, namely, 760 millimetres of mercury, but at different temperatures, 50° C. and 60° C. The temperature of each being increased by 10° C., find which has its pressure most increased.

(46.) The temperature of the air in an extensible spherical envelope is gradually raised 25° C., and the envelope is allowed to expand till its radius is five times its original length; compare the pressure of the air in the two cases.

(47.) The air in a spherical globe 1 foot in diameter is compressed into another globe 6 inches in diameter, and the temperature is raised by 20° C.; compare the pressures of the air in the two cases. Also compare the pressures on the surfaces of the globes.

(48.) 200 cubic centimetres of hydrogen are measured at 60° F. and 29 inches barometrical pressure; what would the gas measure at 0° C. and 760 millimetres mercurial pressure?

(49.) If 200 cubic inches of gas, whose temperature is 60° F. and pressure 30 inches, be raised to 280°, and its pressure reduced to 20 inches, calculate its volume.

(50.) What is the weight of 1 cubic decimetre of dry air at 0° C. and 760 millimetres barometric pressure?

(51.) What is the weight of 1 cubic decimetre of dry air at *760 millimetres* barometric pressure, at the temperatures 20°,

40°, 60°, 100°, 150°, and 200° C. respectively? Put the results in a tabular form.

(52.) At what temperature is the density of air at atmospheric pressure half the density at 0° C.? What will be the velocity of sound in air at this temperature?

(53.) Compare the weight of 1,000 cubic decimetres of dry air under a pressure of 760 millimetres of mercury and at a temperature of 15° C. with the weight of 2,000 cubic decimetres of dry air under a pressure of 500 millimetres of mercury and at a temperature of 200° C., the coefficient of expansion of air being taken as ·003665 for 1° C.

(54.) A barometer with a brass scale which has been adjusted at 0° C. stands at 778 millimetres when the temperature is 20° C. What pressure in kilogrammes per square centimetre does this indicate?

(55.) In an experiment to determine the density of atmospheric air, a glass globe was used whose internal capacity was exactly 10 litres. When it was filled with dry air at a temperature of 18° C. and barometric pressure of 754 millimetres it weighed 12·01 grammes more than it did after so much air had been pumped out that the pressure-gauge only indicated 5 millimetres pressure; deduce from this the density of atmospheric air at a temperature 0° C. and 760 millimetres barometric pressure.

(56.) A gramme of gas at 200° C. measured ·45, and a gramme of another gas at 91° C. measured ·5 of a litre; compare the weights of equal volumes of the two gases at 100° C.

(57.) At what temperature will the density of oxygen gas at ·5 of a metre pressure be the same as that of hydrogen at 0° C. and 2 metres barometric pressure?

(58.) Reduce 70 cubic inches of gas, barometer 29 inches and thermometer at 42° F., to the volume at barometer 30 inches and thermometer 60° F.

(59.) A hollow glass globe, whose neck is closed by a stopcock and can be screwed into an air-pump, is filled with oxygen gas, whose temperature is 35° C., and pressure equal to 780 millimetres of mercury. If the capacity of the globe be 4 litres, find the weight of the gas at the standard temperature and pressure.

(60.) A cubic inch of water which weighs 252·458 grains will produce a cubic foot of steam at atmospheric pressure; find the specific gravity of steam.

(61.) Determine from the following observations the density of carbonic acid gas:

Weight of glass balloon full of dry air =192 grammes.
" " exhausted . . =181 "
" " full of carbonic acid =197·77 "

(62.) A signal gun was fired from a ship, and an observer on shore noticed that 15 seconds elapsed between the time of his seeing the flash and hearing the report. The temperature at the time was 60° F.; what was the distance of the ship?

(63.) An observer noticed that the interval between his seeing a flash of lightning and hearing the thunder was 30 seconds, the temperature of the atmosphere being 82° F.; what was the distance from him of the thunder-cloud?

(64.) A certain volume of dry air weighs 50 grains when the temperarure is 0° C. and pressure 30 inches of mercury; what would be the weight of an equal volume of air at 25° C. under a pressure of 40 inches of mercury?

(65.) A gas measures 117·9 cubic inches at 9·9° C. and 700·9 millimetres mercurial pressure; required, its volume at 0° C. and 1 metre mercurial pressure.

(66.) A gas measures 25 cubic centimetres at 14° C. under a pressure of 350 millimetres of mercury; what volume will it occupy at 0° C. under a pressure of 760 millimetres of mercury?

(67.) If the density of air at 50° F. with barometer at 30 inches be called unity, what will be the density of air at 32° F. with barometer at 29 inches?

APPARENT AND REAL EXPANSION.

(1.) What is meant by the 'absolute,' and what by the 'apparent' expansion of a liquid? Knowing that the coefficient of absolute expansion of mercury is $\frac{1}{5550}$, and its coefficient of apparent expansion in a particular kind of glass is $\frac{1}{6480}$, find the coefficient of cubical expansion of glass.

(2.) A thermometer tube open at the top and filled with mercury contains 1,000 grains at 32° F.; if the tube be heated till its temperature is 84°, find how many grains of mercury will be expelled; the expansion of mercury in volume between 32° and 212° being ·018, and the linear expansion of glass between those points ·0008.

(3.) A cylindrical glass tube whose internal diameter at 10° C. is 4 millimetres contains a quantity of mercury at the same temperature which occupies a length of 20 centimetres in the tube. If, now, the tube and mercury be heated up to 70° C., find the space occupied by the mercury, the coefficient of cubical dilatation of mercury being $\frac{1}{5550}$, and that for glass $\frac{1}{38700}$.

(4.) Assuming that the mean coefficient of expansion of mercury for 1° C. is ·0001815, and that of the glass of a thermometer ·000026, find the reading of such a thermometer, of which the bulb is plunged into water at the temperature of 100° C., while the stem is exposed to air of the temperature 10° C.

(5.) Assuming the same coefficients of expansion as in the last example, find the true temperature of the air if the bulb is plunged into boiling water and the reading of the scale be 98·8° C.

(6.) It is required to construct a mercurial thermometer by means of which we can measure temperatures of 200° C. above and 40° C. below zero; what must be the ratio of the internal capacity of the bulb to be blown on the tube to that of the tube itself?

(7.) A glass tube is divided into 260 parts of equal internal capacity, and when it is weighed empty and then with a column of mercury which takes up 40 subdivisions, the difference of the weights is 2 grammes; what must be the radius of the bulb which we must blow on this tube, in order that the 260 divisions of the tube may be equal to 180 centesimal degrees?

(8.) If a thermometer plunged incompletely in a liquid whose temperature is required indicate a temperature of 72·5° C., and 15° C. be that of the air, the column not immersed being 40 degrees, prove that the correction to be applied is ·36 of a degree, $\frac{1}{6480}$ being the expansion of mercury in glass for 1° C., assuming that the temperature of the mercury in each part is that of the medium which surrounds it.

(9.) There is half a cubic inch of mercury in a thermometer at 32° F.; when the temperature is raised to 92° F. the mercury ascends 4 inches; what is the diameter of the bore of the glass tube?

(10.) The weight of mercury which completely filled a weight-thermometer at 0° C. was 264 grammes. The thermometer was then raised to a temperature of 100° C., and kept at that till the mercury ceased to issue from it. The thermometer was then weighed again, and it was found that the mercury which remained in it weighed only 260 grammes. Find the coefficient of apparent expansion of mercury. What is the coefficient of absolute expansion of mercury? (The vessel was of soft soda-glass.)

(11.) A globular glass vessel has a narrow neck with a mark on it. The quantity of benzol which at 0° C. exactly fills this vessel up to the mark weighs 19·76 grammes. The vessel and its contents are then heated up to 60·5° C. All the liquid which is above the mark is then removed, and on weighing again it is found that the amount of benzol remaining in the vessel weighs 18·47 grammes. Find both the *apparent* and absolute coefficients of expansion of benzol.

DENSITY OF THE ATMOSPHERE.

(1.) If 55·721 grammes be the apparent weight of a body of specific gravity 2·653 weighed in air with platinum weights at a temperature of 13° C., and pressure 770 millimetres, what is the true weight of the body? (Neglecting the effect of temperature on the solid.)

(2.) A piece of cork, varnished over, weighed in air 3·255 grammes when the barometer was at 29·48 inches, and the thermometer at 12·5° C.; a leaden bullet weighed in water 20·53 grammes, the temperature of the water being the same as that of the room. The two being fastened together and weighed in the same water at the same temperature and pressure, were found to weigh 3·94 grammes; find the specific gravity of the cork.

(3.) Find the specific gravity of a sample of gun-metal from the following observations:

Weight of piece of the metal in air = 18·53 grammes.
„ „ „ water = 16·37 „
Height of barometer in laboratory = 761·73 mms.
Temperature of the air and water = 13·5° C.

(4.) Calculate the specific gravity of some sulphuric ether from the following set of observations, made with the specific gravity flask:

Weight of flask empty . . = 18·316 grammes.
Weight of flask filled with distilled water . . . . = 83·093 „
Weight of flask filled with sulphuric ether . . . = 65·350 „
Temperature of the water . = 13·5° C.
„ „ ether . = 13° C.
„ „ air . = 12·9° C.
Barometric height . . . = 29·66 inches.

(5.) Find the specific gravity of some small fragments of a heavy substance from the following observations, made with the specific gravity flask:

Weight of flask filled with distilled water . . . . . = 83·039 grammes.
Weight of flask with the fragments and filled up with water . . = 86·267 ,,
Weight of the metallic fragments in air . . . . . = 3·503 ,,
Temperature of the air and water = 13° C.

(6.) In latitude 21° on the mountain of Guanaxato, in Mexico, Baron Humboldt made the following observations:

	Lower station.	Upper station.
Thermometer in open air	77°·6	70°·4.
,, attached to barometer . . .	77°·6	70°·4.
Barometric height . .	30·05 in.	23·66 in.

What was the difference of level between the two stations?

(7.) According to General Roy, the mean height of the barometer on Carnarvon Quay was observed to be 30·151 inches, the temperature of the mercury and also that of the air 59°·9 F. On the top of Snowdon the height of the mercury was 26·474 inches, the temperature of the mercury 50°·88, that of the air 49°·1 F. Find the height of Snowdon above Carnarvon Quay.

(8.) Near the summit of Chimborazo the barometer was observed by Humboldt to fall 14·85 inches, the attached thermometer being then at 50° F., and the detached one at 29°·12 F. The same barometer carried down to the shore of the Pacific Ocean rose to 30 inches, while both the attached and detached thermometers stood at 77°·54 F. What was the height attained to by the traveller?

(9.) To determine the height of Mont Blanc, Saussure made barometric observations at two stations, the upper one of which was 3·3 feet below the summit of the mountain, and the lower one 1345·4 feet above the level of the sea :

	Upper station.	Lower station.
Barometric height in French inches	27·267	16·042.
Temperature as shown by attached thermometer . .	22°·6 R.	2°·3 R.

Latitude = 45°·45.

Find the height of the mountain.

(10.) Find the height of Arthur's Seat from the following observations: at Leith Pier the height of the barometer was 29·567 inches ; the attached thermometer indicated 55°·25, while the detached one was 54°. On the summit of Arthur's Seat the barometer was 28·704 inches, the attached thermometer was 51°·75, and the detached thermometer 50°·5. The latitude is 56° N.

(11.) The following observations were made simultaneously at the summit and at the base of a mountain in latitude 43° :

	Upper station.	Lower station.
Barometric height in millimetres	537·2.	735·58.
Attached thermometer. .	9°·75 C.	18°·625 C.
Detached „ . .	4° C.	19°·125 C.

Calculate the height of the mountain.

(12.) Determine from the following observations the height above the lower station of the summit of the Erzgebirg:

	Lower station.	Upper station.
Barometric height in millimetres	736·52.	716·9.
Temperature of mercury by attached thermometer .	7°·6 R.	6°·4 R.
Temperature of air by detached thermometer .	7°·8 R.	6°·2 R.

Latitude 51° 34'.

LATENT HEAT OF WATER.

(1.) Two thin glass flasks were suspended in a room at the temperature of 8·5° C., one containing water at 0° and the other the same weight of ice at 0° C. At the end of half an hour the temperature of the water had risen 4° C., and at the end of 10½ hours the ice had melted and assumed the same temperature. Find the number of thermal units required to melt a pound of ice at 0° C.

(2.) Three kilogrammes of ice at 0° C. were immersed in 7 kilogrammes of water at 100° C., producing a mass of water of 46°·2 C. temperature; find from these data the amount of heat rendered latent in the melting of each kilogramme of ice.

(3.) Find the temperature of the water obtained by pouring 4 kilogrammes of boiling water over 3 kilogrammes of ice.

(4.) A mass of ice at 0° C. was exposed to a constant source of heat, and it was observed that it took 8 minutes to reduce the mass to water of a temperature 0° C. It took 10 minutes more to raise the temperature of the water to 100° C., and thenceforward the temperature remained constant, till after a further interval of 54 minutes the whole of the water had been converted into steam. Deduce from this experiment the latent heat of water, and also that of steam.

(5.) If a mass of water be kept perfectly still it can be cooled down to 10 degrees or even more below the ordinary freezing temperature; if, however, it be then disturbed, immediately a portion of it becomes solid. What proportion does this part bear to the whole?

(6.) A piece of ice at 0° C., weighing 92 grammes, was thrown into a quantity of water weighing 1,200 grammes, whose temperature was 22° C.: what would be the temperature of the water when all the ice had just melted?

(7.) A piece of ice at 0° C., weighing 1,000 grammes, was thrown into 2,000 grammes of water at 25° C. : how much ice will have been melted when the water has just cooled down to 0° C.? It is assumed that the water receives no heat from without.

(8.) The heat of fusion of ice is 80°, and the heat of fusion of lead is 5·4 ; the specific heat of solid lead is ·0314 and the melting point of lead is 326°, all these numbers being related to the Centigrade scale. How much ice must melt to reduce a pound of barely melted lead to solid lead at 0° C.?

(9.) How much snow at 0° C. must be added to an ounce of alcohol at 10° C. to reduce its temperature to 0° C., the specific heat of alcohol being ·67?

(10.) To what temperature above the melting point could a given mass of tin be raised if it were possible to apply all the heat which would become latent in its fusion, simply to raising its temperature?

(11.) It has sometimes been supposed, from the low latent as well as sensible heat of the vapours of alcohol and ether, that they might be economically substituted for steam as sources of mechanical power. Prove numerically that even if alcohol and ether could be procured as cheap as water, the latter would be the most economical.

TENSION OF VAPOURS AND HYGROMETRY.

(1.) What weight of aqueous vapour is contained in a cubic foot of atmospheric air at 25° C., which is fully saturated?

(2.) What would be the corresponding weight if the air were not fully saturated and the dew-point 12° C.?

(3.) A quantity of steam at 100° C. is removed from contact with water, and is then heated up to 121° C. in a confined space, so that it cannot expand; find the resulting tension.

(4.) If 1,700 cubic feet of steam at 100° C. were removed from contact with water and then heated up at constant pressure to 121° C., what space would this mass of steam occupy?

(5.) A quantity of saturated steam at 100° C. is heated, not in contact with water, up to 130° C.: what will be the tension of this superheated steam if it cannot expand?

(6.) Find the pressure exerted on every square inch of the inside of the upper surface of a closed vessel in which water is heated up to 165°·5 C.

(7.) The temperatures as indicated on the two scales of a dry and wet bulb hygrometer on a certain day were 14° C. and 11° C., and the height of the barometer was 752 millimetres: find the temperature of the dew-point and the proportion of aqueous vapour in the air.

(8.) A quantity of dry air measures 1,000 cubic centimetres at 10° C., and 760 millimetres pressure. If the same quantity of air is heated to 30° C. and saturated with aqueous vapour at that temperature, what must be the volume of the moist air in order that the pressure may remain unchanged?

(9.) The temperature of the air in a laboratory was observed to be 24°, and that of the dew-point (observed by means of Daniell's hygrometer) was 13° C.; what was the ratio of the amount of aqueous vapour in the air to that of complete saturation?

(10.) Imagine a portion of the atmosphere 1,000 feet high, and extending over a space one mile square, which is at a uniform temperature of 20° C., and fully saturated with vapour; how much rain will be produced from this if the temperature falls to 11° C.?

(11.) What would be the quantity of rain if, instead of being saturated with aqueous vapour, the dew-point of the air at 20° C. was 15° C.?

(12.) Two equal volumes of air, one at 16° C. and the other at 4° C., each saturated with vapour, are intermingled: find the temperature of the mixed air and the amount of vapour which will be precipitated in the form of cloud.

(13.) The dew-point is 12° C. and the temperature of the room 16°·5 C.; find the hygrometric state of the air in the room.

(14.) The barometer stands at 29·88 inches, and the thermometer is at the dew-point; a barometer and a cup of water are placed under a receiver, from which the air is removed, and the barometer then stands at ·36 of an inch: find the space which would be occupied by a given volume of the atmosphere if it were deprived of its vapour without changing its pressure or temperature.

(15.) On a certain day the external thermometer of a Daniell's hygrometer indicated 60° F., and the internal one fell to 48° F. before the ring of dew appeared; on the next day the external thermometer stood at 66° F. and the internal one had only fallen to 64° F. when the dew-ring appeared; compare the degrees of dryness of the atmosphere on these two occasions.

(16.) On another occasion the temperature of the air in the room was found to be 15° C., while that of the dew-point was 10°. Assuming 1,000 to represent the amount of vapour in the air when fully saturated, find the degree of moisture at the time of the above observation.

(17.) From the following data you are required to give the volume of the dry gas at 0° C. and 760 millimetres mercurial pressure:—

Observed volume of moist gas = 68·6 cub. inches.
" height of barometer = 738·5 millimetres.
" temperature . . = 15° C.
Height of mercury in eudio*meter above* level of the *mercury in trough* . . } = 147·5 millimetres.

DENSITY OF VAPOURS.

(1.) One volume of oxygen and two volumes of hydrogen when combined produce two volumes of steam of the same temperature and tension: find from this the density of the steam with respect to the atmosphere.

(2.) By experiment it was found that a given weight of steam at 100° C. and 760 millimetres of barometric pressure occupied 1,700 times the space that an equal weight of water at 0° C. did, and also that atmospheric air at 0° C. and the same barometric pressure took up 770 times as much room as an equal weight of water at 0° C.; deduce from this the ratio of the density of steam to that of air at 100° C. and 760 millimetres barometric pressure.

(3.) What is the density of saturated aqueous vapour at 40° C.?

(4.) Find the weight of a cubic foot of steam at 100° C.

(5.) What weight of water is contained in a cubic foot of aqueous vapour at 25° C.?

(6.) What is the density of saturated aqueous vapour at a temperature of 121° C.? Also find the space occupied by the saturated steam at 121° C. temperature, obtained from one cubic foot of water.

(7.) Find the density of saturated steam at a tension of 5 atmospheres. What is the weight of a cubic foot of this steam?

(8.) What is the weight of 1,000 cubic feet of air saturated with aqueous vapour at a temperature of 25° C. and 750 millimetres pressure?

(9.) Calculate the density of alcohol vapour from the following experimental data :—

Weight of flask at 18° C. . = 50·8 grammes.
" " filled with alcohol vapour . . = 50·8245 "
Temperature of flask when sealed . . = 167°
Capacity of flask . . . = 351.5 c.cms.

(10.) In an experiment to determine by Dumas' method the vapour density of a liquid the following observations were made. The internal capacity of the glass globe was found to be 10,000 cubic centimetres. Its weight, when filled with air at 0° C., was 1,015 grammes, and when filled with vapour and hermetically sealed its weight was found to be 1,010 grammes. Calculate from these data the density of this vapour with reference to atmospheric air at 0° C.

(11.) To determine the vapour density of ether the following observations were made :

Weight of glass balloon full of atmospheric air at 10° C., and 752·3 millimetres barometric pressure = 19·515 grammes.

Weight of balloon full of ether vapour and sealed at 60° C. and 753·4 millimetres pressure was = 19·745 grammes.

Capacity of balloon = 160 cubic centimetres.

Calculate from these data the density of ether vapour.

(12.) The weight of a glass ball, its neck drawn out to a fine tube, filled with dry air at 30 inches pressure, and 60° F., was 1,334·89 grains. Its capacity was 28·66 cubic inches. Some chloroform was introduced, converted into vapour, and as soon as the vapour ceased to issue, the tube was hermetically sealed; the temperature of the ball at the moment of sealing being 213° F. and the barometric pressure 30·494 inches. The weight of the ball, filled with vapour, was 1,354·21 grains. The point of the tube was now broken off under mercury, and the ball was found to contain 0·3 inches of residual air. What is the specific gravity of chloroform vapour?

(13.) Calculate the density of camphor vapour with respect to hydrogen from the following numbers, obtained by Dumas according to his method :

Temperature of the air, 13°·5 C. Barometer, 742 millimetres.

Temperature of the bath at the moment of sealing the globe, 244° C.

Increase of the weight of the globe, ·708 grammes.

Volume of mercury required to fill the globe, 295 cubic centimetres.

(14.) The density of the vapour of iodine was determined according to Dumas' method as follows. The flask containing the iodine was heated in an oil bath up to 200° C., and when all the iodine in it had been converted into vapour, it was sealed up and weighed when cold. The following were the observations :

Weight of air-free flask . = 45·5 grammes.
Capacity of flask . . = 300 cub. cms.
Weight of flask full of iodine vapour at 200° C. . . = 47·4634 grammes.

Calculate from these data the density of the vapour of iodine.

(15.) The following observations were made in an experiment to determine, according to Dumas' method, the density of the vapour of alcohol:

	Grains.
Weight of balloon full of dry air at 29·1 inches barometric pressure, and at a temperature of 57° F. . . .	1,187·20

	Grains.
Weight of balloon full of alcohol vapour, sealed at 212° F., the barometer standing at 29·1 inches	1189·20
Weight of the balloon with the water that entered on opening the capillary neck under water	8102·00
Residual air at 57° F.	·20 cub. in.

Calculate from these data the density of the vapour of alcohol at a temperature of 60° F. and 30 inches barometric pressure.

(16.) The following observations were made in an experiment to determine, according to the method of Gay-Lussac, the vapour density of a substance:

Weight of substance in glass bulb	·3723 gramme.
Observed volume of vapour	100 cubic cms.
Temperature of bath	202° C.
Difference of level of mercury within and without the tube	59 mms.
Height of oil column	319 „
Height of barometer	763 „

Find from these data the specific gravity of the vapour at a temperature of 0° C., and 760 millimetres barometric pressure.

(17.) In a determination of a vapour density by Gay-Lussac's method, the following data were obtained:

Weight of substance	·1163 grammes.
Observed volume of vapour	50·77 cub. cms.
Temperature of bath	215° C.
Height of barometer	755·5 mms.
Difference of level of mercury inside and outside of tube	80·0 „
Height of oil column reduced to millimetres of mercury	16·9 „

Find from these data the specific gravity of the vapour, that of hydrogen being taken as unity.

(18). In another experiment, made according to Hoffman's modification of the method of Gay-Lussac, the following data were obtained:

Weight of substance	·062 gramme.
Observed volume of vapour	57·3 cub. cms.
Temperature of bath	20° C.
Height of barometer	744 mms.
Difference of level of mercury inside and outside of tube	459 „

Find from these data the specific gravity of the vapour.

CONNECTION BETWEEN THE BOILING POINT AND THE PRESSURE.

(1.) If two thermometers were constructed, one at the pole and the other at the equator, and if in both of them 0° is marked at the temperature of melting ice, and 100° at the temperature of steam under the pressure of 760 millimetres of mercury at 0° C., show that the two thermometers will give discordant indications when brought to the same place and compared.

(2.) The temperature of the boiling point as observed on the thermometer scale is correct only when, by an observation of the barometer taken at the same time, the mercury column reduced to 0° C. temperature stands at 760 millimetres. For any other barometric height a correction is necessary. Assuming that the barometric height was 750 millimetres, and the observed distance of the boiling from the freezing point was 112 millimetres, what was the corrected distance?

(3.) The position of the boiling point of a thermometer was determined at a barometric pressure of 749 millimetres. Supposing that the distance between the boiling point, so obtained, and the freezing point be 315 millimetres, how far i above this point will the level of the mercury stand when it indicates a temperature of 100° C.?

(4.) When the boiling point of a certain thermometer was determined and marked, the barometer stood at 768·2 millimetres. The distance between the boiling point, as marked, and the freezing point was 283 millimetres; how far will the surface of the mercury, at a temperature of 100° C., be below the indicated boiling point?

(5.) By means of the hypsometer the boiling point at the lower of two stations was found to be 99°·5 C., and at the upper one 97° C.; find the difference of level of the two stations.

(6.) Assuming that a difference of level of 596 feet produce a difference in the boiling point of water of 1° F., and that at the level of the sea, with the barometer at 30 inches, the boiling point of water is 212° F.; find the heights of the following places.

Place.	Boiling point of water.
Hospice of the St. Gothard	199°·6 F.
Dijon	210°·6 F.
Dresden	211°·3.
Berlin	211°·6.
Summit of Mont Blanc	185°·8.

LATENT HEAT OF VAPOUR.

(1.) A flat-bottomed tin-plate vessel containing some water was placed upon a heated plate; the water was initially at a temperature of 50° F.: in four minutes it acquired the temperature of 212° F., and began to boil; and in twenty minutes the whole had evaporated. Calculate from this experiment the latent heat of steam.

(2.) Water was heated under pressure (in a Papin's *digester*) to 400° F.; the valve was then opened, when part of the water rushed out in the form of steam, and the temperature of the remainder sank to 212°; it was found that only one-fifth of the water had gone off as steam; deduce from this experiment the latent heat of steam.

(3.) 10·81 grammes of steam at 100° C. is condensed by 526·25 grammes of water at 14°, contained in a copper vessel weighing 250 grammes; the temperature of the whole is then found to be 26°. Find from these data the latent heat of steam at 100° C., assuming that no loss or gain of heat has taken place from without. (Specific heat of copper = ·095.)

(4.) How many pounds of steam at 100° C. will just melt 20 lbs. of ice at 0° C.?

(5.) One pound of steam is passed into a vessel containing 5 lbs. of water at a temperature of 20° C., and then condensed; what will be the temperature of the mixed steam and water?

(6.) If the steam from 4 lbs. of boiling water be conducted into 60 lbs. of water at 0° C., what will be the resulting temperature?

(7.) How many pounds of steam at 121° C. are required to raise the temperature of 300 lbs. of water from 11° to 28° C.?

(8.) The latent heat of steam at atmospheric pressure being 536, how much steam at this pressure must be condensed in a gallon of water at 5° C. that the temperature of the whole may be 50° C.?

(9.) A tenth of a pound of steam at atmospheric pressure and temperature 100° C. is discharged into 10 lbs. of water at 5° C.; what will be the temperature of the mixture?

(10.) The steam from 1 lb. of water is condensed by 5·4 lbs. of water at 0° C.; what is the temperature of the resulting 6·4 lbs. of water?

(11.) The worm tub of a still contained initially 120 lbs. of water at 0° C., and after the steam from 2 lbs. of water had passed through the worm the temperature of the water in the tub was observed to be 40° C., while that of the condensed steam was also 40° : deduce from this experiment the latent heat of steam.

(12.) The worm tub of a still contained 60 cubic decimetres of water at an initial temperature of 8° C. The retort contained water which was to be boiled. After 2 litres of distilled water had passed over, the temperature of the water in the worm tub was found to be 28°·5 C. Calculate from this the latent heat of steam.

(13.) In the same apparatus, and under exactly similar circumstances, some spirits of wine was distilled. After 3 kilogrammes of spirits of wine had been distilled over, the temperature of the 60 cubic decimetres of water in the worm tub had risen from 8° to 22° C. Calculate the latent heat of the vapour of spirits of wine.

(14.) The same experiment was repeated with ether, and the temperature of the 60 kilogrammes of water was raised from 8° C. to 17° C.; after that 5 kilogrammes of ether had been distilled. Calculate the latent heat of ether vapour.

(15.) The condenser of a still contains 420 grammes of water at 10° C. ; what will be the temperature of the water in three successive experiments when (*a*) 15 grammes of water, (*b*) 25 grammes of spirits of wine, (*c*) 35 grammes of ether have been distilled over?

(16.) Assuming that the area of the Mississippi Valley is 982,000 square miles, and that the mean annual rainfall is 40 inches, find the number of tons of coal that would have to be burnt to produce the same amount of heat as is annually set free among the clouds that give rain to this valley.

(17.) How many cubic inches of water at 60° F. are required for the condensation of the steam generated from one cubic inch of water, the temperature after condensation being 100° F.?

(18.) An ounce of steam at 212° F. is added to a pound of water at a temperature of 50°; what will be the temperature of the mixture?

(19.) What weight of water at 60° F. must be mixed with 20 lbs. of steam, of one atmosphere, in order to produce water at 120° F.?

(20.) The temperature of the injection water of a condensing engine is 60°, the steam enters the condenser at a temperature of 212°, the water pumped out of the condenser is at a temperature of 110°; what weight of injection water must be supplied for each pound of steam which enters the condenser?

(21.) Two ounces of water at 60° are placed in an evaporating dish which is covered, except by a small opening, by a glass plate. The flame of a gas-burner causes the water to boil in $3\frac{1}{3}$ minutes, and the whole is evaporated after 22 minutes more have elapsed. What should you infer to be the latent heat of steam from this experiment?

SPECIFIC HEAT.

(1.) Determine the specific heat of mercury from the observation that, when the same vessel is filled successively with water and mercury and heated to the same temperature, the water and the mercury cool through the same number of degrees in 10 minutes and 270 seconds respectively. The specific gravity of mercury is here considered constantly equal to 13·6.

(2.) The specific heat of water is four times, and its density 770 times, that of air. Supposing a cubic mile of water to yield up one degree of its heat, by what quantity would 1,000 cubic miles of the atmosphere be heated?

(3.) A small hole was made in a block of ice, in imitation of Black's calorimeter, and a leaden bullet weighing 98 grammes and heated up to 100° C. was dropped in and a lid of ice put on. The bullet was left in for a few minutes and then removed, and the water produced by the melting of the ice removed by a pipette and found to measure

3·75 cubic centimetres. The hole was then enlarged, and 98 grammes of boiling water were poured in. This was stirred about by a thermometer till it had cooled to 0° C. Then all the water in the hole was removed by the pipette and found to measure 220·5 cubic centimetres. Deduce from this experiment the specific heat of lead.

(4.) In the hole in a block of ice an iron ball weighing 200 grammes and heated up to 100° was placed, and the hole covered up with a plate of ice. When the ball had cooled to 0° C. it was found that 293 grammes of ice had been melted. Calculate from these data the specific heat of iron.

(5.) A pound of olive oil and a pound of water contained in thin glass flasks were brought from a cold room, whose temperature was 40°, to a warm room whose temperature was 70° C.; compare the times which elapsed before each had acquired the same temperature as the room.

(6.) How much snow at 0° C. must be added to an ounce of alcohol at 10° C. to reduce its temperature to 0° C., the specific heat of alcohol being ·67?

(7.) Ten grammes of sodic chloride at 91° C. having been immersed in 125 grammes of oil of turpentine at 13° C., the temperature of the mixture was 16°. Find from these data the specific heat of sodic chloride, supposing no loss or gain of heat to have taken place from without, and taking the specific heat of oil of turpentine = 0·428.

(8.) A pound of mercury at a temperature of 102° C. is immersed in a pound of water at 40° C.; how many degrees will the temperature of the water be raised?

(9.) A substance weighing 6 lbs. at a temperature of 100° C. is plunged into 20 lbs. of water at a temperature of 20° C. contained in a copper vessel, the specific heat of which is ·09515, and whose weight is 8 lbs. The temperature of the mixture is found to be 25° C. Find the specific heat of the substance. Find also the temperature of the mixture when half a pound of ice at 0° C. is added.

(10.) A substance weighing 200 grammes at a temperature of 97° C. is mixed with 500 grammes of water at 20° C., and the temperature of the mixture is 25° C.; find the specific heat of the substance, (1) neglecting the heat absorbed by the vessel containing the water, (2) allowing for the heat absorbed, and assuming that the vessel weighs 300 grammes and that its specific heat is ·095.

(11.) If the specific heat of mercury be ·033, what will be the temperature of a mixture of 5 lbs. of mercury at 100° C. with 5 lbs. of water at 16° C.?

(12.) The following experiment was made by Count Rumford:—To 4,590 grains of water at the temperature of 59½° F. were added 1,016⅛ grains of gunmetal, in thin slips, separated from the gun by means of a fine saw, these slips being at the temperature of 210° F. When they had remained together one minute and had been well stirred about by means of a small rod of light wood, the heat of the mixture was found to be 63° F. Find the specific heat of the metal.

(13.) If 15 ounces of sand at 65° C. (spec. heat ·215), and 12 ounces of iron at 40° C. (spec. heat ·11) be thrown into 8 ounces of water at 15° C., find the temperature of the mixture.

(14.) If 7 lbs. of water at 25° be mixed with 3 lbs. of water at 65° C., find the temperature of the mixture.

(15.) What will be the temperature of a mixture of 6 lbs. of mercury at 20° C. and 4 lbs. of mercury at 50° C.?

(16.) 10 lbs. of iron at 100° C. were immersed in 18 lbs. of water at 15°, and the resulting temperature was observed to be 20°. Determine from this the specific heat of iron.

(17.) 1 lb. of mercury at 100° C. was mixed with 1 lb. of water at 7°, and the temperature of the mixture was observed to be 10° C. Determine the specific heat of mercury.

(18.) 8 lbs. of water at 100° C. are mixed with 10 lbs.

of mercury at 22°·5 C.; find the temperature of the mixture.

(19.) 15 lbs. of mercury at 10° C. are mixed with 8 lbs. of iron at 60° C. Taking the specific heat of iron at ·1138, find the temperature of the mixture.

(20.) How many units of heat are necessary to raise the temperature of 793 grammes of mercury by 45° C.?

(21.) How many units of heat are necessary to raise 60 kilogrammes of iron from 10° C. to 150° C.?

(22.) How many units of heat must be imparted to a mass of alcohol (spec. grav. ·833) weighing 1,523 grammes, to raise its temperature from 15° C. to 63° C.?

(23.) Some scraps of iron which, together, weighed 60 grammes, and which were heated up to 100° C., were thrown into 180 grammes of water at a temperature of 19° C. When the temperature of the two was thoroughly equalised, that of the water was found to have risen to 22° C. Calculate from this the specific heat of iron.

(24.) In an experiment to determine the specific heat of mercury, 80 grammes of it were heated up to 98° C., and the mass was then thrown into a glass flask containing 112 grammes of water at 10° C. After being well agitated, the water was found to have risen in temperature to 12° C. Deduce the specific heat of mercury.

(25.) Determine from the results of the following experiment the specific heat of benzol: 43·5 grammes of benzol at 65° C. were poured into a small flask containing 100 grammes of water at 8° C., and after a good shaking the tmeperature of the mixture was found to be 15°·5 C.

(26.) 250 grammes of water at 5° C. and 250 grammes of turpentine at 50° were shaken together: what was the temperature of the mixture?

(27.) If the specific heat of iron be ·11, and the latent heat of steam 967, calculate the change of temperature which *would be produced* in a bar of iron weighing 100 lbs. by *the amount of heat* necessary to convert 1 lb. of water *at 62° F. into steam.*

(28.) The amount of heat required to raise 31·7 kilogrammes of copper 1° C. is only half what is required to raise 1 kilogramme of hydrogen to the same temperature; deduce the atomic weight of copper.

(29.) Having given that the specific heats of mercury and platinum are ·0319 and ·0324 respectively, that the atomic weight of mercury is 200, and its atomic heat 6·3800, find the atomic weight of platinum.

(30.) A small brass vessel, weighing 97·5 grammes, was cooled down to 0° C., and in it was placed a litre of alcohol at 0° C. The whole was then heated to 50° C., and then immersed in a kilogramme of water at 10° C., contained in a brass calorimeter weighing 201·3 grammes. The temperature of the water, after a short interval of time, was found to be 24° C. Deduce from this the specific heat of alcohol, the specific gravity of alcohol being ·8, and the specific heat of brass 0·1.

(31.) In an experiment with Laplace's ice calorimeter a copper ball weighing 3 kilogrammes, and which had been heated up to 100° C., was introduced into the calorimeter, whereupon ·38 of a kilogramme of water escaped from the apparatus; hence determine the specific heat of copper.

(32.) In another experiment with the same calorimeter 5 kilogrammes of iron at 80° C. melted ·57 of a kilogramme of ice; find the specific heat of iron.

(33.) The mean specific heat of iron being found by experiment to be

·1088 between 0° and 50° C.
·1124 „ 0° „ 100° „
·1160 „ 0° „ 150° „

Find what is its true specific heat at 0°, 50°, 100°, and 150° C. respectively.

(34.) In an experiment to determine the specific heat of a sample of commercial zinc according to Regnault's method, the following observations were made:—

Weight of copper cage in air . .	25·17 grammes.
„ „ „ + zinc in air .	138·067 „
„ copper calorimeter . .	129·73 „
„ calorimeter + water . .	603·17 „
Temperature of water in calorimeter before the zinc was in . .	12·5° C.
Temperature of cage + zinc when taken from hot chamber. .	97·5° C.
Temperature of water, cage, and zinc after immersion . .	14·6°
Specific heat of copper of cage . .	·09515

Find from these data the specific heat of the sample of zinc.

(35.) In determining the specific heat of a sample of oil of turpentine by Regnault's method, a glass test-tube full of it was weighed, together with the string supporting it, and then, after being heated, it was dropped into the calorimeter and the experiment went on just as in the case of a solid. The following observations were made :—

Weight of the string . . .	·271 grammes.
„ test-tube + string . .	2·745 „
„ test-tube, string and turpentine . .	5·475 „
„ calorimeter . . .	129·73 „
„ copper calorimeter + water	290·9
Specific heat of copper . . .	·09515
„ „ „ glass . . .	·19768
Temperature of water in calorimeter, initially . . .	10°·6 C.
Temperature of tube when taken from the bath . . .	98°·5 C.
Temperature of water, tube, and turpentine at end of experiment	11°·6 C.

Find from these data the specific heat of the given sample *of oil of turpentine.*

(36.) In an experiment with Rumford's calorimeter, the mass of the calorimeter filled with liquid was equivalent to 2,781 grammes of water. A wax taper, carefully weighed, was placed under the mouth of the tube and lighted. The temperature of the air was 16°·1111, that of the water 13°.3333. The experiment was continued till the temperature was brought to 18°·8889; the taper was then extinguished, and, being weighed, was found to have lost 1·63 grammes of white wax. Find the quantity of caloric evolved by the combustion of 1 gramme of white wax.

(37.) In order to find the heat of a smelting furnace a platinum ball weighing 100 grammes was introduced into it, and after remaining there some time was withdrawn and plunged into a mass of water whose weight was one kilogramme and temperature 9° C., and when the temperatures had become equalised, the resultant temperature was found to be 13° C.; what was the temperature of the furnace?

(38.) An iron ball weighing 83 grammes and heated up to 340° C. was plunged into 50 grammes of water at 10° C.; when the ball had thoroughly cooled, what was the temperature of the water?

(39.) A platinum ball weighing 200 grammes was heated in a furnace and then plunged into 1,000 grammes of water. In consequence of this the temperature of the water rose from 13° to 20° C. What was the temperature of the furnace?

(40.) 200 grammes of molten tin at 300° C. are poured into 1,000 grammes of water at 12° C.; what will be the temperature of the water after the tin has solidified and thoroughly cooled down?

(41.) The capacity for heat of mercury being ·033, how much, at the temperature of 240°, will be sufficient to raise 12 lbs. of water from 50° to 58°?

(42.) 1 lb. of cold iron is placed in 1 lb. of water at a temperature of 200° F. The water loses 5° of temperature. How much has the iron gained in temperature?

(43.) The specific heat of air is 0.25 ; its specific gravity is $\frac{1}{770}$, water being unity. A cubic foot of water at 70° F. is placed in contact with 100 cubic feet of air at 50° ; the water sinks to 69°. Supposing all the heat that the water has lost to be communicated to the air, what would be the exaltation of the temperature of the air ?

MECHANICAL EQUIVALENT OF HEAT.

(1.) Two pieces of iron weighing 10 lbs. each are dropped, one from the top of a tower 350 feet high and the other from a window 50 feet lower down, on to a hard non-conducting surface at its base : what will be the rise in temperature of each of these pieces of iron due to the fall, the specific heat of iron being ·1138?

(2.) A solid ball of platinum falls from a height of 40 metres on to a rigid, inelastic surface ; find the number of degrees by which its temperature will be raised.

(3.) It is found that equal weights of water and copper require respectively 100 and 9 units of heat to raise their temperatures by the same amount : find how much a mass of copper would be raised in temperature by striking a hard non-conducting surface after a fall of 368 feet.

(4.) Taking the specific heat of iron at 0·11, with what velocity must a mass of iron strike a hard non-conducting substance to have its temperature raised 1° C. ?

(5.) Assuming that air is raised 0°·41 C. in temperature by a compression of $\frac{1}{273}$, find the increase of temperature due to compression when a stream of air descends a shaft 360 feet deep.

(6.) What must be the velocity of a leaden bullet that the heat generated by its collision with a target may be just sufficient to melt the bullet, the melting-point being 326° C., the specific heat of solid lead ·0314, the latent heat of fusion 5°·4, and the initial temperature 10° C. ?

(7.) From what height must a block of ice at 0° C. fall *that the heat generated* by its collision with the earth shall

be just competent to melt it? From what height must it fall that the heat generated may be sufficient to convert it into steam?

(8.) A lump of lead weighing 15 lbs. falls from a height of 150 feet on to a hard non-conducting surface; find the number of degrees on Fahrenheit's scale by which its temperature will be raised.

(9.) The mean specific heat of lead between 0° C. and any temperature t° being $= \cdot 0286 + \cdot 000019t$, its melting-point being 326° C. and the latent heat of fusion 5·36962; find the smallest velocity with which a leaden bullet must strike a target in order that the heat produced by the impact may be just sufficient to melt the bullet, its temperature before impact being 16° C.

(10.) If a train weighing 30 tons and moving with a velocity of 10 miles an hour be stopped in 100 feet by the brake power, what number of units of heat will be generated by the friction?

(11.) If the coefficient of friction be ·05, and a railway carriage, whose mass is 2 tons, and moving with a velocity of 10 miles an hour, be gradually stopped by the friction, how many units of heat will be developed?

(12.) How much heat (in water-pound degrees) is produced by stopping a railway train weighing 60 tons, and running on a level at the rate of 45 miles an hour?

(13.) If the train were running at the same rate down an incline of 1 in 100, and went on moving with a uniformly retarded velocity for 15 minutes after the brakes were put on, how much additional heat would be produced?

(14.) A railway train weighs 80 tons, and the friction is 7 lbs. a ton; determine the number of units of heat that must be expended in drawing it for 4 miles up an incline of 1 in 200.

(15.) A railway train, including the engine, weighs 100 tons, and the resistance is 8 lbs. per ton; determine the smallest number of units of heat which will have to be expended by the steam in a run of 100 miles on a level road.

(16.) A railway truck, weighing with its contents 10 tons, the resistance being 8 lbs. per ton, is drawn from rest by a horse; after going 300 feet it is observed to be moving at the rate of 5 feet per second. Find the number of units of heat (in water-pound degrees) which have been expended by the horse in doing this work.

(17.) A train weighing 90 tons comes to the foot of an incline of 1 in 160 with a velocity of 30 miles an hour; the resistance is 7 lbs. per ton, and the length of the incline is 2 miles; at the top of the incline the train has a velocity of 20 miles an hour. How many units of heat have been expended by the steam in getting the train up the incline?

(18.) What number of units of heat will have to be expended to raise in 4½ minutes 4 cwt. of material from a depth of 80 fathoms by a rope, each foot of which weighs 1·125 lbs.?

(19.) How much work can the steam from 1 lb. of water do?

(20.) In a double-action condensing steam-engine, the diameter of the piston is 16½ inches, its length of stroke 4 feet, and it makes 48 strokes per minute. The steam pressure is 16½ lbs. and the opposing pressure 1½ lbs. to the square inch; calculate from this the useful effect of the engine and the amount of water it will require. (The useful effect is generally taken as half the theoretical effect.)

(21.) In a high-pressure steam-engine the area of the piston is ½ square foot, its velocity 5 feet a second, the inflowing steam has a tension of 5 atmospheres, and it can escape freely on the other side of the piston by a sufficiently large aperture; find the useful effect of the engine and the necessary water supply.

(22.) In the combustion of 800 cubic centimetres of hydrogen, measured at 0° C., and under a pressure of 760 millimetres, 200 grammes of water contained in a copper calorimeter weighing 400 grammes were heated through 10°·2 C.; calculate from these data how many grammes of water would be heated 1° C. by the combustion of 1 gramme of hydrogen.

(23.) A bar of wrought-iron 100 feet long, with a section of 2 square inches, has its temperature raised from 32° F. to 212° F.; how many units of work has the heat done?

(24.) The pumping apparatus of a mine is connected with the engine by means of a series of wrought-iron rods 200 feet long; the section of each rod is $\frac{3}{4}$ of a square inch; the strain is estimated at 6 tons; how many units of heat are used up at every stroke in the elongation of the bars?

(25.) A cube of iron one decimetre in the side is heated up from the freezing to the boiling point of water; show that the exterior work done by it in expanding against the pressure of the atmosphere is less than $\frac{1}{10}$ of a kilogrammetre.

(26.) A cylinder, whose cross-section was equal to ·0003688 square metres, and in the base of which was a very small orifice, contained water. This was pressed upon by a piston weighing 177 kilogrammes. When the piston had descended 1 metre it was found that 1,000 kilogrammes of water had escaped with no appreciable velocity, and that the temperature of this water had risen by 1°·0457. Supposing that 10 kilogrammes of pressure were used in overcoming the resistance of the cylinder to the motion of the piston, find the mechanical equivalent of heat.

(27.) Having given

(1.) Specific gravity of mercury . .	13·596
(2.) Weight of 1 litre of air at 0° C. and 760 millimetres pressure	1·2932 grammes.
(3.) Specific heat of air at constant pressure	·0237
(4.) Specific heat of air at constant volume	·0167

Find the mechanical equivalent of heat.

(28.) If the mechanical equivalent of heat be taken as 425 metre-kilogrammes, what is this in foot-pounds?

(29.) How many foot-pounds are required to convert 1 lb. of ice at 0° C. into 1 lb. of steam at 100° C.?

(30.) A cannon-ball weighing 7 lbs. strikes an iron target with a velocity of 400 feet per second. Supposing the whole of the motion to be converted into heat and the heat to be uniformly distributed through 70 lbs. of the target, what change of temperature will be produced, assuming the mechanical equivalent of heat as 1,390 foot-pounds?

(31.) Determine from the following experiment the ratio of the specific heat of air at constant pressure to that of air at constant volume, and deduce from this ratio the mechanical equivalent of heat: A definite quantity of air was introduced into a vessel in which it could expand freely so that the pressure remained constant, and its temperature was raised, by means of a constant source of heat, in 14 minutes from 0° to 273° C., and consequently its volume was doubled. The same mass of air being inclosed in a vessel in which it was not able to expand, was raised by the same source of heat in 10 minutes from 0° C. to 273° C.

(32.) A body weighing 100 lbs. moves without rotation at the rate of 20 miles an hour; find the number of units of heat which would be developed if its motion were suddenly stopped.

(33.) A 68-pound cannon-ball strikes a target at a velocity of 1,400 feet a second. Supposing all the heat generated by the collision to be communicated to 68 lbs. of water at 60° F., how many degrees would the temperature of the water be raised?

(34.) I burn 1 lb. of a sample of coal in such a manner as to convey the whole of the heat to 100 lbs. of water at 20° C. At the conclusion of the experiment I find that the temperature of the water has been raised to 80° C. I require to know the evaporating power of the coal, or the number of pounds of *boiling* water which 1 lb. of the coal will convert into steam; also the mechanical equivalent (expressed either in foot-tons or metre-kilogrammes) of the amount of heat evolved from 1 lb. of the coal.

(35.) 1 lb. of coal gives out, during combustion, 12,000 *units of* heat; how much work in horse-power could be *done by burning 1 lb. of* coal if there were no waste?

(36.) A weight of a ton is lifted by a steam-engine to a height of 386 feet; what is the amount of heat consumed in this act?

(37.) 1,000 cubic feet of water has to be raised to a height of 200 feet per minute: the question is, how many units of heat will have to be expended, supposing that one quarter of the power is lost through friction and other causes?

(38.) Steam enters a cylinder at 15 lbs. pressure; it is cut off at one-third of the stroke, the resistance of the uncondensed vapour averaging 2 lbs. per inch; find the mean effective steam pressure.

(39.) The piston of an engine moves through 12 inches under a pressure of 30 lbs. on the square inch; the steam is then cut off from the boiler, and allowed to expand. What will be its pressure when the piston has moved through another 6 inches?

(40.) The length of the stroke of an engine is 8 feet, the pressure of the steam on entering the cylinder is 30 lbs. on the inch; at what point should the steam be cut off so that the pressure at the end of the stroke may be 5 lbs. per inch?

(41.) The initial pressure of steam in a cylinder whose stroke is 5 feet 4 inches is 45 lbs. and expansion commences when 2 feet 3 inches have been performed; find the pressure at the end of the stroke. Find also the horse-power, if the area of the cylinder is 2,218 square inches, and the number of strokes per minute 30.

CONDUCTION OF HEAT.

(1.) Calculate the quantity of heat lost per hour from each square metre of the surface of an iron steam-boiler 0·8 centimetres in thickness, when the temperature of the inner surface of the boiler is 120°, and that of the outer surface $119\frac{1}{2}$° C., the coefficient of conductivity of iron being 11·5 (referred to 1 centimetre as unit of length, 1 minute as unit of time, and the quantity of heat required to raise the temperature of 1 gramme of water from 0° C. to 1° C. as *unit of heat*).

(2.) The walls of a cottage are 50 centimetres thick, and made of brick: how much heat will be lost per hour per square metre from the exterior face of the walls if the temperature inside the cottage be kept constant at 16° C., while the temperature of the air outside is $-5°$ C., the conductivity of brick being taken at ·34?

(3.) The temperature of a large room is kept at 21° C. by a large iron stove, the temperature of the interior of which is kept constant at 200° C. : if the thickness of the stove be 1 centimetre, find how much heat will be given off per hour from every square metre of its exterior face.

(4.) The rays of the sun in passing through a window do not perceptibly heat the panes of glass; but if a glass screen be placed in front of the fire it soon becomes sensibly warm. What is the reason of this?

(5.) When a thermometer was surrounded with a body of quicksilver it required to be immersed in boiling water for $36\frac{2}{3}$ seconds to produce a rise of a certain number of degrees, but to produce the same rise when surrounded in the same manner by water 117 seconds were necessary. Compare the conducting powers of water and mercury.

(6.) At a certain Turkish bath the cool room is separated from the first hot room by a large plate of glass. The lower portion of this glass is in the form of a rectangle 4·3 metres high and 2·4 metres broad, while the upper portion is in the form of three-quarters of a circle of 1·2 metres radius. The thickness of the glass is 2 centimetres. On a certain day the temperature of the hot room was 52° C., and that of the cold room 18° C. Assuming the conductivity of glass to be ·87, find the number of kilogrammes of water which could be raised from 0° C. to 100° C. by the heat given off per hour from this plate (the centimetre, gramme, minute, being the units employed).

ANSWERS.

CONVERSION OF THERMOMETRIC SCALES.

(1.) 18°·4 R. (2.) 172°·4 F. (3.) 76°·25 C.
(4.) 33°·8 C. (5.) 32°·4 R. (6.) +5° F.
(7.) 39°·02 F. (8.) 15°·5 C. (9.) 23° F.
(10.) −20° C. (11.) −40° F. (12.) ·65 mm., ·361 mm.
(13.) 1·05 mm. and ·583 mm. (14.) 10° C. (15.) 10° C.

LINEAR EXPANSION OF SOLIDS.

(1.) 2·50086 metres. (2.) ·3004 metre. (3.) ·49962 metre.
(4.) 2·006456 metres. (5.) 2·000576 metres. (6.) 200·0887 feet.
(7.) 199·956 feet. (8.) ·0000173. (9.) 1·80167 metres.
(10.) 15·0098 feet. (13.) 9·504 oscil. (14.) $\frac{1}{8}$, nearly.
(15.) 5·0046 feet. (16.) 3, nearly. (17.) 20° C.
(18.) 10·0098 feet. (19.) 759·94 mms. (20.) 730·04 mms.
(21.) 761·65 mms. (22.) 756·07 mms. (23.) 29·621 inches.
(24.) 29·172 inches. (25.) 29·312 inches. (26.) −1°·16 C.
(27.) 20·03552 sq. decims. (28.) ·1086 sq. centims.
(29.) 10·0022 sq. feet, 9·9978 sq. feet. (30.) 748·63 mms.
(31.) ·257 inch. (32.) 188 miles, 78 yards, 3·2 inches.

CUBICAL EXPANSION OF BODIES.

(1.) ·997152 cub. ft., 1·0013295 cub. ft. (2.) 1·00216 litres.
(3.) 5·0096 centims. (4.) 27·085795 cub. decims.
(5.) 1,002·58 cub. centims. (6.) 11·2558.
(7.) ·0000087, ·000007. (8.) ·000014. (9.) ·00439.
(10.) 4·4329 cub. centims. (11.) 13·176. (12.) ·05357.
(13.) ·0417. (14.) 6°·858 C. (15.) 1·092 lits.
(16.) 1·042 litres. (17.) ·77745.
(18.) 5·072 cub. centims. (19.) $24\frac{204}{555}$ cub. centims.

(20.) $20\frac{5}{8}$ litres. (21.) 13·563.
(22.) 3·056 cub. inches. (23.) 68°·13 F. (24.) ·0556.
(25.) $\frac{1}{5550}$.
(26.) 913·15 mms.
(27.) 136·63 cub. inches. (29.) 726·25 mms. (30.) 1·2932 lits.
(32.) 1,071·14 cub. feet. (33.) 1·2592 grammes.
(34.) As 40 : 2523. (35.) 71·539 lbs. (36.) 22° C.
(37.) 1,743·4 cub. metres. (38.) 3·749 grammes.
(39.) 5,581·375 cub. centims. (40.) 3,677° C.
(41.) 1,133·49 cub. inches. (42.) 3·5 and 4·1413 atmospheres.
(43.) 90 inches. (44.) 146·79 cub. centims.
(46.) As 573 : 1, nearly. (47.) ·11647 and ·46588.
(48.) 183·32 cub. centims. (49.) 434·32 cub. inches.
(50.) 1·2932 grammes. (51.) 1·2048, 1·1279, 1·0601, ·9464,
(52.) 273° C., 1,229·2 ft. per sec. ·8344, ·7462.
(53.) As 5 : 4. (54.) 1·0545. (55.) ·0012995.
(56.) As 14 : 9. (57.) 823°·76 C.
(58.) 70·145 cub. inches. (59.) ·52018 gramme. (60.) ·64626.
(61.) 1·524. (62.) 3·1873 miles.
(63.) $6\frac{1}{2}$ miles, nearly. (64.) 61·074 grains.
(65.) 79·744 cub. inches. (66.) 10·952 cub. centims.

APPARENT EXPANSION OF LIQUIDS.

(1.) ·0000259. (2.) 4·944 grains. (3.) 20·185 centims.
(4.) 98°·56 C. (5.) 20° C. (6.) As 27 : 1.
(7.) 2·02 centims. (9.) ·0309 inch. (10.) $\frac{1}{8500}$, $\frac{1}{5577}$.
(11.) ·001154, ·001179.

DENSITY OF AIR.

(1.) 55·744 grammes, nearly. (2.) ·1534. (3.) 8·548.
(4.) ·72643. (5.) 10·6477. (6.) 6,843·7 feet.
(7.) 3,554 feet. (8.) 19,227 feet. (9.) 15,818·1 feet.
(10.) 801·3 feet. (11.) 8,579·9 ft. (12.) 724·6 feet.

LATENT HEAT OF WATER.

(1.) 80. (2.) 79·3. (3.) $22\frac{6}{7}$. (4.) 80° and 540°.
(5.) $\frac{1}{8}$. (6.) 14°·74 C. (7.) 625 grammes. (8.) ·1955 lbs.
(9.) ·084 ounce. (10.) 490° C.

TENSION OF VAPOURS.

(1.) ·02462 oz. (2.) ·01018 oz. (3.) 803 mms.

(4.) 1,800 cub. feet. (5.) 821·12 mms. (6.) 103·32.

(7.) 8°·08 C., ·6772. (8.) 1028·2 cub. centms. (9.) ·5, nearly.

(10.) 27,550 cub. feet. (11.) 11,804 cub. feet.

(12.) An amount represented by ·651 mms. of mercurial pressure.

(13.) ·745. (14.) $V' = V \times$ ·99072. (15.) As 1·4428 : 1.

(16.) 721·6. (17.) 49·469 cub. inches.

DENSITY OF VAPOURS.

(1.) ·62. (2.) ·61895. (3.) ·000051.

(4.) ·594 oz. (5.) ·023 oz. (6.) $\frac{1}{889}$, 889 cub. ft.

(7.) $\frac{1}{384}$, 2·6 oz. (8.) 73·29 lbs. (9.) 1·631. (10.) $\frac{8}{13}$.

(11.) 2·533. (12.) 4·1273. (13.) 76·33

(14.) 8·7698. (15.) 1·617. (16.) 5·25.

(17.) 50·29. (18.) 2·3951.

VARIATION OF THE BOILING-POINT WITH THE PRESSURE.

(2.) 112·44 mms. (3.) 1·29 mms. (4). ·94 mm.

(5.) 2,720 feet. (6.) 6,808, 712, 295, 131.

LATENT HEAT OF VAPOUR.

(1.) 810. (2.) 940. (4.) 2·5.

(5.) 100° C. (6.) 40° C. (7.) 8·33 lbs.

(8.) ·768 lbs. (9.) 11°·25 C. (10.) 100° C.

(13.) 216. (14.) 78·8. (15.) 31°·83 C., 26°·44 C., 18°·92 C.

(16.) 30,000 × 6,540,000 tons. (17.) 26·3.

(18.) 114°·2 F. (19.) 380 lbs. (20.) 20·84 lbs.

(21) 1,003°·2.

SPECIFIC HEAT.

(1.) ·03308. (2.) 3°·08. (3.) ·03. (4.) ·1172.

(5.) As 1 : 2. (6.) ·084 oz. (7.) ·214. (8.) 4°·85.

(9.) ·2307 (10.) ·0902, ·183. (11.) 18·68.

(12.) ·1075. (13.) 27°·74. (14.) 37°. (15.) 32°.

(16.) ·1125. (17.) $\frac{1}{30}$. (18.) 96°·9. (19.) 42°·3 C.

(20.) 1·1883 units. (21.) 955·92. (22.) 68·718. (23.) ·11538.

(24.) ·032558. (25.) ·3788. (26.) 18°·22 C. (27.) $101\frac{8}{11}$.
(28.) 63·4. (29.) 196·91. (30.) ·93028. (31.) ·1013.
(32.) ·114. (33.) ·1053, ·1125, ·1197, ·1269. (34.) ·0737.
(35.) ·5523. (36.) As much as would melt 126·3748 grammes
(37.) 1,247°·6 C. (38.) 62°·44 C. [of ice at 0° C.
(39.) 3,059°·6 C. (40.) 13°·69 C. (41.) 1·9169 lbs.
(42.) 43°·94. (43.) 30°·8 F.

MECHANICAL EQUIVALENT OF HEAT.

(1.) 3°·98, 3°·41 F. (2.) 2°·9 C. (3.) 5°·297 F.
(4.) 32·89 feet per sec. (5.) $1°\frac{1}{11}$ C. (6.) 290 metres per sec.
(7.) 33,681 metres, 270,810 metres. (8.) 6°·187 F.
(9.) 302·4 metres per sec. (10.) 2·948 units per foot of rail.
(11.) ·029016 units per foot of rail. (12.) 11,775·6 units.
(13.) 63·06 units. (14.) 39,832·5 units. (15.) 547,150 units.
(16.) 42·422 units. (17.) 21,463·7 units. (18.) 446·42 units.
(19.) 58,752 foot-pounds. (20.) 9·34 h.p., 10·06 cub. feet of water
(21.) 18·3 h.p., 23·438 cub. feet of water per hour. [per hour.
(22.) 33,867·2. (23.) 3,875 units. (24.) 1·07513.
(26.) 434 kilogrammetres. (27.) 418·12 kilogrammetres.
(28.) 3,074·7 foot-pounds. (29.) 999,734 foot-pounds. (30.) 1°·57.
(31.) As 14 : 10. (32.) 1·73069 units. (33.) 39°·376.
(34.) $11\frac{1}{9}$ lbs., 8,337,600 foot-pounds. (35.) $280\frac{8}{11}$.
(36.) 1,120 units. (37.) 21,588·9 units. (38.) 9·9708 lbs.
(39.) 20 lbs. (40.) 1 foot 4 inches.
(41.) 18·9844 lbs., 380 h.p.

CONDUCTION OF HEAT.

(1.) Sufficient heat to raise 172·55 kilos. of water from 0° to 100° C.
(2.) 18·36 kilos. of water 1° C. (3.) 10,350 kilos. of water from 0°
(5.) As ·31332 : 1. [to 100° C.
(6.) Sufficient to raise 130·572 kilos. of water from 0° to 100° C.

LONDON : PRINTED BY
SPOTTISWOODE AND CO., NEW-STREET SQUARE
AND PARLIAMENT STREET